ing position and, by enabling such occupants to store music preferences, e.g., a radio station, the speakers associated with each seating position can be controlled to provide music from the respective radio station. The speakers could also be automatically directed or orientatable so that at least one speaker directs sound toward each occupant present in the vehicle. Speakers which cannot direct sound to an occupant would not be activated.

Thus, one of the more remarkable advantages of the improved audio reception system and method disclosed herein is that by monitoring the position of the occupants, the entertainment system can be controlled without manual input to optimize audio reception by the occupants.

The maximum acoustic frequency that is practical to use for acoustic imaging in the systems is about 40 to 160 kilohertz (kHz). The wavelength of a 50 kHz acoustic wave is about 0.6 cm which is too coarse to determine the fine features of a person's face, for example. It is well understood by those skilled in the art that features which are smaller than the wavelength of the irradiating radiation cannot be distinguished. Similarly the wavelength of common radar systems varies from about 0.9 cm (for 33,000 MHz K band) to 133 cm (for 225 MHz P band) which is also too coarse for person identification systems. In FIG. **6**, therefore, the ultrasonic transducers of the previous designs are replaced by laser transducers **231** and **232** which are connected to a microprocessor **101**. In all other manners, the system operates the same. The design of the electronic circuits for this laser system is described in some detail in U.S. Pat. No. 5,653,462 cross-referenced above and in particular FIG. **8** thereof and the corresponding description. In this case, a pattern recognition system such as a neural network system is employed and uses the demodulated signals from the receptors **231** and **232**.

The output of processor **101** of the monitoring system is shown connected schematically to a general interface **290** which can be the vehicle ignition enabling system; the entertainment system; the seat, mirror, suspension or other adjustment systems; or any other appropriate vehicle system.

There are two preferred methods of implementing the vehicle interior monitoring system of this invention, a microprocessor system and an application specific integrated circuit system (ASIC). Both of these systems are represented schematically as either **101** or **601** herein. In some systems, both a microprocessor and an ASIC are used. In other systems, most if not all of the circuitry is combined onto a single chip (system on a chip). The particular implementation depends on the quantity to be made and economic considerations. A block diagram illustrating the microprocessor system is shown in FIG. **7**A which shows the implementation of the system of FIG. **1**. An alternate implementation of the FIG. **1** system using an ASIC is shown in FIG. **7**B. In both cases the target, which may be a rear facing child seat, is shown schematically as **110** and the three transducers as **131**, **132**, and **133**. In the embodiment of FIG. **7**A, there is a digitizer coupled to the receivers **131**,**133** and the processor, and an indicator coupled to the processor. In the embodiment of FIG. **7**B, there is a memory unit associated with the ASIC and also an indicator coupled to the ASIC.

In FIG. **8**, a view of the system of FIG. **1** is illustrated with a box **295** shown on the front passenger seat in place of a rear facing child seat The vehicle interior monitoring system is trained to recognize that this box **295** is neither a rear facing child seat nor an occupant and therefore it is treated as an empty seat and the deployment of the airbag is suppressed. This training is accomplished using a neural network with the commercially available software disclosed above and provided, for example, by NeuralWare of Pittsburgh. The system assesses the probability that the box is a person, however, and if there is even the remotest chance that it is a person, the airbag deployment is not suppressed. The system is thus typically biased toward enabling airbag deployment.

Side impact airbags are now used on some vehicles. Some are quite small compared to driver or passenger airbags used for frontal impact protection. Nevertheless, a small child could be injured if he is sleeping with his head against the airbag module when the airbag deploys and a vehicle interior monitoring system is needed to prevent such a deployment. In FIG. **9**, a single ultrasonic transducer **330** is shown mounted in a door adjacent airbag system **332** which houses an airbag **336**. Similar to the embodiment in FIG. **4** with reference to U.S. Pat. No. 5,653,462, the airbag system **332** and components of the interior monitoring system, e.g., transducer **330**, are coupled to a processor **110**A including a control circuit **101**B for controlling deployment of the airbag **336** based on information obtained by ultrasonic transducer **330**. This device is not used to identify the object that is adjacent the airbag but merely to measure the position of the object. It can also be used to determine the presence of the object, i.e., the received waves are indicative of the presence or absence of an occupant as well as the position of the occupant or a part thereof. Instead of an ultrasonic transducer, another wave-receiving transducer may be used as described in any of the other embodiments herein, either solely for performing a wave-receiving function or for performing both a wave-receiving function and a wave-transmitting function.

A rear-of-head detector **334** is also illustrated in FIG. **9**. This detector **334** is used to determine the distance from the headrest to the rearmost position of the occupant's head and to therefore control the position of the headrest so that it is properly positioned behind the occupant's head to offer optimum support during a rear impact. Although the headrest of most vehicles is adjustable, it is rare for an occupant to position it properly if at all. Each year there are in excess of 400,000 whiplash injuries in vehicle impacts approximately 90,000 of which are from rear impacts (source: National Highway Traffic Safety Admin.). A properly positioned headrest could substantially reduce the frequency of such injuries, which can be accomplished by the head detector of this invention. The head detector **334** is shown connected schematically to the headrest control mechanism and circuitry **340** This mechanism is capable of moving the headrest up and down and, in some cases, rotating it fore and aft.

When the driver of a vehicle is using a cellular phone, the phone microphone frequently picks up other noise in the vehicle making it difficult for the other party to hear what is being said. This noise can be reduced if a directional microphone is used and directed toward the mouth of the driver. This is difficult to do since the position of drivers' mouths varies significantly depending on such things as the size and seating position of the driver. By using the vehicle interior identification and monitoring system of this invention, and through appropriate pattern recognition techniques, the location of the driver's head can be determined with sufficient accuracy even with ultrasonics to permit a directional microphone having a 15 degree cone angle to be aimed at the mouth of the driver resulting in a clear reception of his voice. The use of directional speakers in a similar manner also improves the telephone system

performance. In the extreme case of directionality, the techniques of hypersound can be used. Such a system can also be used to permit effortless conversations between occupants of the front and rear seats. Such a system is shown in FIG. **10** which is a system similar to that of FIG. **2** only using three ultrasonic transducers **231**, **232** and **233** to determine the location of the driver's head and control the pointing direction of a microphone **355**. Speaker **357** is shown connected schematically to the phone system **359** completing the system.

The transducers **231** and **232** are placed high in the A-pillar and the third transducer **233** is placed in the headliner and displaced horizontally from transducers **231** and **232**. The two transducers **231** and **232** provide information to permit the determination of the locus of the head in the vertical direction and the combination of one of transducers **231** and **232** in conjunction with transducer **233** is used to determine the horizontal location of the head. The three transducers are placed high in the vehicle passenger compartment so that the first returned signal is from the head. Temporal filtering is used to eliminate signals which are reflections from beyond the head and the determination of the head center location is then found by the approximate centroid of the head returned signal. That is, once the location of the return signal centroid is found from each of the three received signals from transducers **231**, **232** and **233**, the distance to that point is known for each of the transducers based on the time it takes the signal to travel from the head to each transducer. In this manner, by using the three transducers plus an algorithm for finding the coordinates of the head center, using processor **101**, and through the use of known relationships between the location of the mouth and the head center, an estimate of the mouth location, and the ear locations, can be easily determined within a circle having a diameter of about five inches (13 cm). This is sufficiently accurate for a directional microphone to cover the mouth while excluding the majority of unwanted noise.

The headlights of oncoming vehicles frequently make it difficult for the driver of a vehicle to see the road and safely operate the vehicle. This is a significant cause of accidents and much discomfort. The problem is especially severe during bad weather where rain can cause multiple reflections. Visors are now used to partially solve this problem but they do so by completely blocking the view through a large portion of the window and therefore cannot be used to cover the entire windshield. Similar problems happen when the sun is setting or rising and the driver is operating the vehicle in the direction of the sun. The vehicle interior monitoring system of this invention can contribute to the solution of this problem by determining the position of the driver's eyes. If separate sensors are used to sense the direction of the light from the on-coming vehicle or the sun, and through the use of electro-chromic glass, a liquid crystal device, or other appropriate technology, a portion of the windshield can be darkened to impose a filter between the eyes of the driver and the light source. Electro-chromic glass is a material where the color of the glass can be changed through the application of an electric current. By dividing the windshield into a controlled grid or matrix of contiguous areas and through feeding the current into the windshield from orthogonal directions, selective portions of the windshield can be darkened as desired. Other systems for selectively imposing a filter between the eyes of an occupant and the light source are currently under development.

FIG. **11** illustrates how such a system operates. A sensor **410** located on vehicle **402** determines the direction of the light **412** from the headlights of oncoming vehicle **404**. Sensor **410** is comprised of a lens and a charge-coupled device (CCD), of CMOS light sensing or similar device, with appropriate electronic circuitry which determines which elements of the CCD are being most brightly illuminated. An algorithm stored in processor **101** then calculates the direction of the light from the oncoming headlights based on the information from the CCD, or CMOS device. Transducers **231**, **232** and **233** determine the probable location of the eyes of the operator **210** of vehicle **402** in a manner such as described above in conjunction with the determination of the location of the driver's mouth in the discussion of FIG. **10**. In this case, however, the determination of the probable locus of the driver's eyes is made with an accuracy of a diameter for each eye of about 3 inches (7.5 cm). This calculation sometimes will be in error and provision is made for the driver to make an adjustment to correct for this error as described below.

The windshield **416** of vehicle **402** is made from electrochromic glass or comprises a liquid crystal device or similar system, and is selectively darkened at area **418** due to the application of a current along perpendicular directions **422** and **424** of windshield **416**. The particular portion of the windshield to be darkened is determined by processor **101**. Once the direction of the light from the oncoming vehicle is known and the locations of the driver's eyes are known, it is a matter of simple trigonometry to determine which areas of the windshield matrix should be darkened to impose a filter between the headlights and the driver's eyes. This is accomplished by processor **101**. A separate control system, not shown, located on the instrument panel, or at some other convenient location, allows the driver to select the amount of darkening accomplished by the system from no darkening to maximum darkening. In this manner, the driver can select the amount of light that is filtered to suit his particular physiology. The sensor **410** can either be designed to respond to a single light source or to multiple light sources to be sensed and thus multiple portions of the vehicle windshield to be darkened.

As mentioned above, the calculations of the location of the driver's eyes using acoustic systems may be in error and therefore provision must be made to correct for this error. One such system permits the driver to adjust the center of the darkened portion of the windshield to correct for such errors through a knob on the instrument panel, steering wheel or other convenient location. Another solution permits the driver to make the adjustment by slightly moving his head. Once a calculation as to the location of the driver's eyes has been made, that calculation is not changed even though the driver moves his head slightly. It is assumed that the driver will only move his head to center the darkened portion of the windshield to optimally filter the light from the oncoming vehicle. The monitoring system will detect this initial head motion and make the correction automatically for future calculations.

Electro-chromic glass is currently used in rear view mirrors to darken the entire mirror in response to the amount of light striking an associated sensor. This substantially reduces the ability of the driver to see objects coming from behind his vehicle. If one rear-approaching vehicle, for example, has failed to dim his lights, the mirror will be darkened to respond to the light from that vehicle making it difficult for the driver to see other vehicles that are also approaching from the rear. If the rear view mirror is selectively darkened on only those portions which cover the lights from the offending vehicle, the driver is able to see all of the light coming from the rear whether the source is bright

or dim. This permits the driver to see all of the approaching vehicles not just the one with bright lights.

Such a system is illustrated in FIG. **12** where rear view mirror **460** is equipped with electro-chromic glass, or comprises a liquid crystal device, having the capability of being selectively darkened, e.g., at area **419**. Associated with mirror **460** is a light sensor **462** that determines the direction of light **412** from the headlights of rear approaching vehicle **405**. In the same manner as above, transducers **231, 232** and **233** determine the location of the eyes of the driver **210**. The signals from both sensor systems, **231, 232** plus **233** and **462**, are combined in processor **101**, where a determination is made as to what portions of the mirror should be darkened, e.g., area **419**. Appropriate currents are then sent to the mirror in a manner similar to the windshield system described above.

Seatbelts are most effective when the upper attachment point to the vehicle is positioned vertically close to the shoulder of the occupant being restrained. If the attachment point is too low the occupant experiences discomfort from the rubbing of the belt on his shoulder. If it is too high, the occupant may experience discomfort due to the rubbing of the belt against his neck and the occupant will move forward by a greater amount during a crash which may result in his head striking the steering wheel. Women in particular experience discomfort from an improperly adjusted seatbelt anchorage point. For these reasons, it is desirable to have the upper seatbelt attachment point located slightly above the occupant's shoulder. To accomplish this for various sized occupants, the location of the occupant's shoulder must be known which can be accomplished by the vehicle interior monitoring system described herein. Such a system is illustrated in FIG. **13** that is a side view of a seatbelt anchorage adjustment system. In this system, a transmitter and receiver (transducer) **520** is positioned in a convenient location, such as the headliner, located above and to the outside of the occupant's shoulder. A narrow elliptical beam **521** of energy is transmitted from transducer **520** in a manner such that it irradiates or illuminates the occupant's shoulder and headrest. An appropriate pattern recognition system as described above is then used to determine the location and position of the shoulder. This information is fed to the seatbelt anchorage height adjustment system **528**, shown schematically, which moves the attachment point **529** to the optimum vertical location.

Acoustic resonators are devices that resonate at a preset frequency when excited at that frequency. If such a device, which has been tuned to 40 kHz, is subjected to ultrasonic radiation at 40 kHz, for example, it will return a signal that is much stronger than the reflected radiation. If such a device is placed at a particular point in the passenger compartment of a vehicle, the returned signal can be easily identified as a high magnitude narrow signal at a particular point in time which is proportional to the distance from the resonator to the receiver. Since this device can be easily identified, it provides a particularly effective method of determining the distance to a particular point in the vehicle passenger compartment (i.e., the distance between the location of the resonator and the detector). If several such resonators are used they can be tuned to slightly different frequencies and therefore separated and identified by the circuitry. Using such resonators, the positions of various objects in the vehicle can be determined. In FIG. **14** for example, three such resonators are placed on the vehicle seat and used to determine the location of the front and back of the seat and the top of the seat back. In this case, transducers **231** and **232**, mounted in the A-pillar **662**, are used in conjunction with resonators **641, 642** and **643** to determine the position of the seat. Transducers **231,232** constitute both transmitter means for transmitting energy signals at the excitation frequencies of the resonators **641,642,643** and detector means for detecting the return energy signals from the excited resonators. Processor **101** is coupled to the transducers **231,232** to analyze the energy signals received by the detectors and provide information about the object with which the resonators are associated, i.e., the position of the seat in this embodiment. This information is then provided to the seat memory and adjustment system, not shown, eliminating the currently used sensors that are placed typically beneath the seat adjacent the seat adjustment motors. In the conventional system, the seat sensors must be wired into the seat adjustment system and are prone to being damaged. By using the vehicle interior monitoring system alone with inexpensive passive resonators, the conventional seat sensors can be eliminated resulting in a cost saving to the vehicle manufacturer. An efficient reflector, such as a parabolic shaped reflector, can be used in a similar manner as the resonator.

Resonators or reflectors, of the type described above can be used for making a variety of position measurements in the vehicle. These resonators are made to resonate at a particular frequency. If the number of resonators increases beyond a reasonable number, dual frequency resonators can be used. A pair of frequencies is then used to identify a particular location. Alternately, resonators tuned to a particular frequency can be used in combination with special transmitters, which transmit at the tuned frequency, which are designed to work with a particular resonator or group of resonators. The cost of the transducers is sufficiently low to permit special transducers to be used for special purposes. The use of resonators which resonate at different frequencies requires that they be irradiated by radiation containing those frequencies.

Another application for a resonator of the type described is to determine the location of the seatbelt and therefore determine whether it is in use If it is known that the occupants are wearing seatbelts, the airbag deployment parameters can be controlled or adjusted based on the knowledge of seatbelt use, e.g., the deployment threshold can be increased since the airbag is not needed in low velocity accidents if the occupants are already restrained by seatbelts. Deployment of other occupant restraint devices could also be effected based on the knowledge of seatbelt use. This will reduce the number of deployments for cases where the airbag provides little or no improvement in safety over the seatbelt. FIG. **15**, for example, shows the placement of a resonator **602** on the front surface of the seatbelt where it can be sensed by the transducers **231** and **232**.

Such a system can also be used to positively identify or confirm the presence of a rear facing child seat in the vehicle, if the child seat is equipped with a resonator. In this case, a resonator **603** is placed on the forwardmost portion of the child seat, or in some other convenient position, as shown in FIG. **1A**. The resonator **603**, or other type of signal generating device which generates a signal upon excitation, e.g., by a transmitted energy signal, can be used not only to determine the orientation of the child seat but also to determine the position of the child seat (in essentially the same manner as described above with respect to determining the position of the seat and the position of the seatbelt).

The determination of the presence of a child seat can be used to affect another system in the vehicle. Most importantly, deployment of an occupant restraint device can be controlled depending on whether a child seat is present.

Control of the occupant restraint device may entail suppression of deployment of the device. If the occupant restraint device is an airbag, e.g., a frontal airbag or a side airbag, control of the airbag deployment may entail not only suppression of the deployment but also depowered deployment, adjustment of the orientation of the airbag, adjustment of the inflation rate or inflation time and/or adjustment of the deflation rate or time.

Other uses for such resonators include placing them on doors and windows in order to determine whether either is open or closed. In FIG. 16A, for example, such a resonator **604** is placed on the top of the window and is sensed by transducers **611** and **612**. In this case, transducers **611** and **612** also monitor the space between the edge of the window glass and the top of the window opening. Many vehicles now have systems which permit the rapid opening of the window, called "express open", by a momentary push of a button. For example, when a vehicle approaches a tollbooth, the driver needs only touch the window control button and the window opens rapidly. Some automobile manufacturers do not wish to use such systems for closing the window, called "express close", because of the fear that the hand of the driver, or of a child leaning forward from the rear seat, or some other object, could get caught between the window and window frame. If the space between the edge of the window and the window frame were monitored with an interior monitoring system, this problem can be solved. The presence of the resonator or reflector **604** on the top of the window glass also gives a positive indication of where the top surface is and reflections from below that point can be ignored.

Various design variations of the window monitoring system are possible and the particular choice will depend on the requirements of the vehicle manufacturer and the characteristics of the vehicle. Two systems will be briefly described here.

In the first example shown in FIG. **16**, a single transmitter/receiver (transducer) **613** is used in place of and located centrally midway between the transducers **611** and **612** shown in FIG. **16**A. A recording of the output of transducer **613** is made of the open window without an object in the space between the window edge and the top of the window frame. When in operation, the transducer **613** receives the return signal from the space it is monitoring and compares that signal with the stored signal referenced above. This is done by processor **601**. If the difference between the test signal and the stored signal indicates that there is a reflecting object in the monitored space, the window is prevented from closing in the express close mode. If the window is part way up, a reflection will be received from the edge of the window glass which, in most cases, is easily identifiable from the reflection of a hand for example. A simple algorithm based on the intensity of the reflection in most cases is sufficient to determine that an object rather than the window edge is in the monitored space. In other cases, the algorithm is used to identify the window edge and ignore that reflection and all other reflections which are lower (i.e. later in time) than the window edge. In all cases, the system will default in not permitting the express close if there is any doubt. The operator can still close the window by holding the switch in the window closing position and the window will then close slowly as it now does in vehicles without the express close feature.

In the second system, two transducers **611** and **612** are used as shown in FIG. **16**A and the processor **601** comprises a neural network. In this example the system is trained for all cases where the window is down and at intermediate locations. In operation, the transducers monitor the window space and feed the received signals to processor **601**. As long as the signals are similar to one of the signals for which the network was trained, the express close system is enabled. As before, the default is to suppress the express close.

The use of a resonator, or reflector, to determine whether the vehicle door is properly shut is illustrated in FIG. **17**. In this case, the resonator **702** is placed in the B-pillar in such a manner that it is shielded by the door, or by a cover or other inhibiting mechanism (not shown) engaged by the door, and prevented from resonating when the door is closed. Resonator **702** provides waves **704**. If transducers such as **231** and **232** in FIG. **3** are used in this system, the closed-door condition would be determined by the absence of a return signal from the B-pillar **702** resonator. This system permits the substitution of an inexpensive resonator for a more expensive and less reliable electrical switch.

The use of an acoustic resonator has been described above. For those cases where an infrared laser system is used, an optical mirror would replace the mechanical resonator used with the acoustic system. In the acoustic system, the resonator can be any of a variety of tuned resonating systems including an acoustic cavity or a vibrating mechanical element.

A neural network, or other pattern recognition system, can be trained to recognize certain people as permitted operators of a vehicle. In this case, if a non-recognized person attempts to operate the vehicle, the system can disable the vehicle and/or sound an alarm as illustrated in FIG. **18**. In this figure the sensing transducers are shown as before as **231**A, **232**A and **233**A, the alarm system schematically as **708** and the alarm as **705**. Since it is unlikely that an unauthorized operator will resemble the authorized operator, the neural network system can be quite tolerant of differences in appearance of the operator. The system defaults to where a key must be used in the case that the system doesn't recognize the driver or the owner wishes to allow another person to operate the vehicle. The transducers **231**A, **232**A and **233**A are sensitive to infrared radiation and the operator is irradiated with infrared waves from transducer **231**A. This is necessary due to the small size of the features which need to be recognized for high accuracy of recognition. An alternate system uses an infrared laser, which can be **231**A in FIG. **18**, to irradiate or illuminate the operator and a CCD or CMOS device, which can be represented as **232**A in FIG. **18**, to receive the reflected image. In this case, the recognition of the operator is accomplished using a pattern recognition system such as described in Popesco, V. and Vincent, J. M. "Location of Facial Features Using a Boltzmann Machine to Implement Geometric Constraints", Chapter 14 of Lisboa, P. J. G. and Taylor, M. J. Editors, *Techniques and Applications of Neural Networks*, Ellis Horwood Publishers, New York, 1993. In the present case a larger CCD element array containing 100,000 or more elements would in many cases be used instead of the 16 by 16 or 256 element CCD array used by Popesco and Vincent. In fact, the field of facial recognition has expanded greatly in the past few years and systems are available that can be used within a vehicle to recognize the operator based on facial features, the pattern of blood vessels in the iris, or other visual biometric features of the operator and particularly those related to the operator's head and particularly his or her face. Naturally, other biometric features can also be used alone or in combination including fingerprints, weight, voiceprint, handprint, etc.

The human mind has little problem recognizing faces even when they are partially occluded such as with a hat,

sunglasses or a scarf, for example. With the increase in low cost computing power, it is now possible to train a rather large neural network, perhaps a modular neural network, to recognize most of those cases where a human mind will also be successful.

Once a vehicle interior monitoring system employing a sophisticated pattern recognition system, such as a neural network or fuzzy logic system, is in place, it is possible to monitor the motions of the driver over time and determine if he is falling asleep or has otherwise become incapacitated. In such an event, the vehicle can be caused to respond in a number of different ways. One such system is illustrated in FIG. **19** and consists of a monitoring system having transducers **231, 232** and **233** plus microprocessor **101,** such as shown in FIG. **7A,** programmed to compare the motions of the driver over time and trained to recognize changes in behavior representative of becoming incapacitated. If the system determines that there is a reasonable probability that the driver has fallen asleep, for example, then it can turn on a warning light shown here as **805** or send a warning sound. If the driver fails to respond to the warning by pushing a button **806**, for example, then the horn and lights can be operated in a manner to warn other vehicles and the vehicle brought to a stop. One novel approach, not shown, would be to use the horn as the button **806**. For a momentary depression of the horn, for this case, the horn would not sound. Naturally other responses can also be programmed.

An even more sophisticated system of monitoring the behavior of the driver is to track his eye motions using such techniques as are described in: Freidman et al., U.S. Pat. No. 4,648,052 "Eye Tracker Communication System"; Heyner et al., U.S. Pat. No. 4,720,189 "Eye Position Sensor"; Hutchinson, U.S. Pat. No. 4,836,670 "Eye Movement Detector"; and Hutchinson, U.S. Pat. No. 4,950,069 "Eye Movement Detector With Improved Calibration and Speed", all of which are incorporated herein by reference in their entirety to the extent the disclosure of these references is necessary. The detection of the impaired driver in particular can be best determined by these techniques. Also, in a similar manner as described in these patents, the motion of the driver's eyes can be used to control various systems in the vehicle permitting hands off control of the entertainment system, heating and air conditioning system or all of the other systems described above. Although some of these systems have been described in the afore-mentioned patents, none have made use of neural networks for interpreting the eye movements

In most of the applications described above, single frequency energy was used to irradiate various occupying items of the passenger compartment. This was for illustrative purposes only and this invention is not limited to single frequency irradiation. In many applications, it is useful to use several discrete frequencies or a band of frequencies. In this manner, considerably greater information is received from the reflected irradiation permitting greater discrimination between different classes of objects. In general each object will have different reflectivities and transmissivities at each frequency. Also, the different resonators placed at different positions in the passenger compartment can now be tuned to different frequencies making it easier to isolate one resonator from another.

Among the inventions disclosed above is an arrangement for obtaining and conveying information about occupancy of a passenger compartment of a vehicle comprises at least one wave-receiving sensor for receiving waves from the passenger compartment, generating means coupled to the wave-receiving sensor(s) for generating information about the occupancy of the passenger compartment based on the waves received by the wave-receiving sensor(s) and communications means coupled to the generating means for transmitting the information about the occupancy of the passenger compartment. As such, response personnel can receive the information about the occupancy of the passenger compartment and respond appropriately, if necessary. There may be several wave-receiving sensors and they may be, e.g., ultrasonic wave-receiving sensors, electromagnetic wave-receiving sensors, capacitance sensors, or combinations thereof. The information about the occupancy of the passenger compartment can include the number of occupants in the passenger compartment, as well as whether each occupant is moving non-reflexively and breathing. A transmitter may be provided for transmitting waves into the passenger compartment such that each wave-receiving sensor receives waves transmitted from the transmitter and modified by passing into and at least partially through the passenger compartment. One or more memory units may be coupled to the generating means for storing the information about the occupancy of the passenger compartment and to the communications means. The communications means then can interrogate the memory unit(s) upon a crash of the vehicle to thereby obtain the information about the occupancy of the passenger compartment. In one particularly useful embodiment, means for determining the health state of at least one occupant are provided, e.g., a heartbeat sensor, a motion sensor such as a micropower impulse radar sensor for detecting motion of the at least one occupant and motion sensor for determining whether the occupant(s) is/are breathing, and coupled to the communications means. The communications means can interrogate the health state determining means upon a crash of the vehicle to thereby obtain and transmit the health state of the occupant(s). The health state determining means can also comprise a chemical sensor for analyzing the amount of carbon dioxide in the passenger compartment or around the at least one occupant or for detecting the presence of blood in the passenger compartment. Movement of the occupant can be determined by monitoring the weight distribution of the occupant(s), or an analysis of waves from the space occupied by the occupant(s). Each wave-receiving sensor generates a signal representative of the waves received thereby and the generating means may comprise a processor for receiving and analyzing the signal from the wave-receiving sensor in order to generate the information about the occupancy of the passenger compartment. The processor can comprises pattern recognition means for classifying an occupant of the seat so that the information about the occupancy of the passenger compartment includes the classification of the occupant. The wave-receiving sensor may be a micropower impulse radar sensor adapted to detect motion of an occupant whereby the motion of the occupant or absence of motion of the occupant is indicative of whether the occupant is breathing. As such, the information about the occupancy of the passenger compartment generated by the generating means is an indication of whether the occupant is breathing. Also, the wave-receiving sensor may generate a signal representative of the waves received thereby and the generating means receive this signal over time and determine whether any occupants in the passenger compartment are moving. As such, the information about the occupancy of the passenger compartment generated by the generating means includes the number of moving and non-moving occupants in the passenger compartment.

A related method for obtaining and conveying information about occupancy of a passenger compartment of a

vehicle comprises the steps of receiving waves from the passenger compartment, generating information about the occupancy of the passenger compartment based on the received waves, and transmitting the information about the occupancy of the passenger compartment whereby response personnel can receive the information about the occupancy of the passenger compartment. Waves may be transmitted into the passenger compartment whereby the transmitted waves are modified by passing into and at least partially through the passenger compartment and then received. The information about the occupancy of the passenger compartment may be stored in at least one memory unit which is subsequently interrogated upon a crash of the vehicle to thereby obtain the information about the occupancy of the passenger compartment. A signal representative of the received waves can be generated by sensors and analyzed in order to generate the information about the state of health of at least one occupant of the passenger compartment and/or to generate the information about the occupancy of the passenger compartment (i.e., determine non-reflexive movement and/or breathing indicating life). Pattern recognition techniques, e.g., a trained neural network, can be applied to analyze the signal and thereby recognize and identify any occupants of the passenger compartment. In this case, the identification of the occupants of the passenger compartment can be included into the information about the occupancy of the passenger compartment.

Other embodiments disclosed above are directed to methods and arrangements for controlling deployment of an airbag. One exemplifying embodiment of an arrangement for controlling deployment of an airbag from an airbag module to protect an occupant in a seat of a vehicle in a crash comprises determining means for determining the position of the occupant or a part thereof, and control means coupled to the determining means for controlling deployment of the airbag based on the determined position of the occupant or part thereof. The determining means may comprise receiver means, e.g., a wave-receiving transducer such as an electromagnetic wave receiver (such as a CCD, CMOS, capacitor plate or antenna) or an ultrasonic transducer, for receiving waves from a space above a seat portion of the seat and processor means coupled to the receiver means for generating a signal representative of the position of the occupant or part thereof based on the waves received by the receiver means. The determining means can include transmitter means for transmitting waves into the space above the seat portion of the seat which are receivable by the receiver means. The receiver means may be mounted in various positions in the vehicle, including in a door of the vehicle, in which case, the distance between the occupant and the door would be determined, i.e., to determine whether the occupant is leaning against the door, and possibly adjacent the airbag module if it is situated in the door, or elsewhere in the vehicle. The control means are designed to suppress deployment of the airbag, control the time at which deployment of the airbag starts, control the rate of gas flow into the airbag, control the rate of gas flow out of the airbag and/or control the rate of deployment of the airbag.

Another arrangement for controlling deployment of an airbag comprises determining means for determining whether an occupant is present in the seat, and control means coupled to the determining means for controlling deployment of the airbag based on whether an occupant is present in the seat, e.g., to suppress deployment if the seat is unoccupied. The determining means may comprise receiver means, e.g., a wave-receiving transducer such as an ultrasonic transducer, CCD, CMOS, capacitor plate, capacitance sensor or antenna, for receiving waves from a space above a seat portion of the seat and processor means coupled to the receiver means for generating a signal representative of the presence or absence of an occupant in the seat based on the waves received by the receiver means. The determining means may optionally include transmitter means for transmitting waves into the space above the seat portion of the seat which are receivable by the receiver means. Further, the determining means may be designed to determine the position of the occupant or a part thereof when an occupant is in the seat in which case, the control means are arranged to control deployment of side airbag based on the determined position of the occupant or part thereof.

One method for controlling deployment of an airbag from an airbag module comprising the steps of determining the position of the occupant or a part thereof, and controlling deployment of the airbag based on the determined position of the occupant or part thereof. The position of the occupant or part thereof is determined as in the arrangement described above.

Another method for controlling deployment of an airbag comprises the steps of determining whether an occupant is present in the seat, and controlling deployment of the airbag based on the presence or absence of an occupant in the seat. The presence of the occupant, and optionally position of the occupant or a part thereof, are determined as in the arrangement described above.

Furthermore, disclosed above are methods for controlling a system in the vehicle based on an occupying item in which at least a portion of the passenger compartment in which the occupying item is situated is irradiated, radiation from the occupying item are received, e.g., by a plurality of sensors or transducers each arranged at a discrete location, the received radiation is processed by a processor in order to create one or more electronic signals characteristic of the occupying item based on the received radiation, each signal containing a pattern representative and/or characteristic of the occupying item and each signal is then categorized by utilizing pattern recognition techniques for recognizing and thus identifying the class of the occupying item. In the pattern recognition process, each signal is processed into a categorization thereof based on data corresponding to patterns of received radiation stored within the pattern recognition means and associated with possible classes of occupying items of the vehicle. Once the signal(s) is/are categorized, the operation of the system in the vehicle may be affected based on the categorization of the signal(s), and thus based on the occupying item. If the system in the vehicle is a vehicle communication system, then an output representative of the number of occupants in the vehicle may be produced based on the categorization of the signal(s) and the vehicle communication system thus controlled based on such output. Similarly, if the system in the vehicle is a vehicle entertainment system or heating and air conditioning system, then an output representative of specific seat occupancy may be produced based on the categorization of the signal(s) and the vehicle entertainment system or heating and air conditioning system thus controlled based on such output. In one embodiment designed to ensure safe operation of the vehicle, the attentiveness of the occupying item is determined from the signal(s) if the occupying item is an occupant, and in addition to affecting the system in the vehicle based on the categorization of the signal, the system in the vehicle is affected based on the determined attentiveness of the occupant.

One embodiment of the interior monitoring system in accordance with the invention comprises means for irradi-

ating at least a portion of the passenger compartment in which an occupying item is situated, receiver means for receiving radiation from the occupying item, e.g., a plurality of receivers, each arranged at a discrete location, processor means coupled to the receivers for processing the received radiation from each receiver in order to create a respective electronic signal characteristic of the occupying item based on the received radiation, each signal containing a pattern representative of the occupying item, categorization means coupled to the processor means for categorizing the signals, and output means coupled to the categorization means for affecting another system within the vehicle based on the categorization of the signals characteristic of the occupying item. The categorization means may use a pattern recognition technique for recognizing and thus identifying the class of the occupying item by processing the signals into a categorization thereof based on data corresponding to patterns of received radiation and associated with possible classes of occupying items of the vehicle. Each signal may comprise a plurality of data, all of which is compared to the data corresponding to patterns of received radiation and associated with possible classes of contents of the vehicle. In one specific embodiment, the system includes location determining means coupled to the processor means for determining the location of the occupying item, e.g., based on the received radiation such that the output means which are coupled to the location determining means, in addition to affecting the other system based on the categorization of the signals characteristic of the occupying item, affect the system based on the determined location of the occupying item. In another embodiment to determine the presence or absence of an occupant, the categorization means comprise pattern recognition means for recognizing the presence or absence of an occupying item in the passenger compartment by processing each signal into a categorization thereof signal based on data corresponding to patterns of received radiation and associated with possible occupying items of the vehicle and the absence of such occupying items.

Also disclosed above is an arrangement for controlling audio reception by at least one occupant of a passenger compartment of the vehicle comprises a monitoring system for determining the position of the occupant(s) and sound generating means coupled to the monitoring system for generating specific sounds. The sound generating means are automatically adjustable based on the determined position of the occupant(s) such that the specific sounds are audible to the occupant(s). The sound generating means may utilize hypersonic sound, e.g., comprise one or more pairs of ultrasonic frequency generators for generating ultrasonic waves whereby for each pair, the ultrasonic frequency generators generate ultrasonic waves which mix to thereby create new audio frequencies. Each pair of ultrasonic frequency generators is controlled independently of the others so that each occupant is able to have different new audio frequencies created. For noise cancellation purposes, the vehicle can include a system for detecting the presence and direction of unwanted noise whereby the sound generating means are coupled to the unwanted noise presence and detection system and direct sound to prevent reception of the unwanted noise by the occupant(s). If the sound generating means comprise speakers, the speakers are controllable based on the determined positions of the occupants such that at least one speaker directs sounds toward each occupant. The monitoring system may be any type of system which is capable of determining the location of the occupant, or more specifically, the location of the head or ears of the occupants. For example, the monitoring system may comprise at least one wave-receiving sensor for receiving waves from the passenger compartment, and a processor coupled to the wave-receiving sensor(s) for determining the position of the occupant(s) based on the waves received by the wave-receiving sensor(s). The monitoring system can also determine the position of objects other than the occupants and control the sound generating means in consideration of the determined position of the objects.

A related method for controlling audio reception by occupants in a vehicle comprises the steps of determining the position of at least one occupant of the vehicle, providing a sound generator for generating specific sounds and automatically adjusting the sound generator based on the determined position of the occupant(s) such that the specific sounds are audible to the occupant(s). The features of the arrangement described above may be used in the method.

Another arrangement for controlling audio reception by occupants of a passenger compartment of the vehicle comprises a monitoring system for determining the presence of any occupants and sound generating means coupled to the monitoring system for generating specific sounds. The sound generating means are automatically adjustable based on the determined presence of any occupants such that the specific sounds are audible to any occupants present in the passenger compartment. The monitoring system and sound generating means may be as in the arrangement described above. However, in this case, the sound generating means are controlled based on the determined presence of the occupants.

Also disclosed above is a system for determining occupancy of a vehicle which comprises a radar system for emitting radio waves into an interior of the vehicle in which objects might be situated and receiving radio waves and a processor coupled to the radar system for determining the presence of any repetitive motions indicative of a living occupant in the vehicle based on the radio waves received by the radar system such that the presence of living occupants in the vehicle is ascertainable upon the determination of the presence of repetitive motions indicative of a living occupant. Repetitive motions indicative of a living occupant may be a heart beat or breathing as reflected by movement of the chest. Thus, for example, the processor may be programmed to analyze the frequency of the repetitive motions based on the radio waves received by the radar system whereby a frequency in a predetermined range is indicative of a heartbeat or breathing. The processor could also be designed to analyze motion only at particular locations in the vehicle in which a chest of any occupants would be located whereby motion at the particular locations is indicative of a heartbeat or breathing. Enhancements of the invention include the provision of means for determining locations of the chest of any occupants whereby the radar system is adjusted based on the determined location of the chest of any occupants. The radar system may be a micropower impulse radar system which monitors motion at a set distance from the radar system, i.e., utilize range-gating techniques. The radar system can be positioned to emit radio waves into a passenger compartment or trunk of the vehicle and/or toward a seat of the vehicle such that the processor determines whether the seats are occupied by living beings. Another enhancement would be to couple a reactive system to the processor for reacting to the determination by the processor of the presence of any repetitive motions. Such a reactive system might be an air connection device for providing or enabling air flow between the interior of the vehicle and the surrounding environment, if the presence of living beings is detected in a closed interior space. The reactive system

could also be a security system for providing a warning. In one particularly useful embodiment, the radar system emits radio waves into a trunk of the vehicle and the reactive system is a trunk release for opening the trunk. The reactive system could also be airbag system which is controlled based on the determined presence of repetitive motions in the vehicle and a window opening system for opening a window associated with the passenger compartment.

A method for determining occupancy of the vehicle disclosed above comprises the steps of emitting radio waves into an interior of the vehicle in which objects might be situated, receiving radio waves after interaction with any objects and determining the presence of any repetitive motions indicative of a living occupant in the vehicle based on the received radio waves such that the presence of living occupants in the vehicle is ascertainable upon the determination of the presence of repetitive motions indicative of a living occupant. Determining the presence of any repetitive motions can entail analyzing the frequency of the repetitive motions based on the received radio waves whereby a frequency in a predetermined range is indicative of a heartbeat or breathing and/or analyzing motion only at particular locations in the vehicle in which a chest of any occupants would be located whereby motion at the particular locations is indicative of a heartbeat or breathing. If the locations of the chest of any occupants are determined, the emission of radio waves can be adjusted based thereon. A radio wave emitter and receiver can be arranged to emit radio waves into a passenger compartment of the vehicle. Upon a determination of the presence of any occupants in the vehicle, air flow between the interior of the vehicle and the surrounding environment can be enabled or provided. A warning can also be provided upon a determination of the presence of any occupants in the vehicle. If the radio wave emitter and receiver emit radio waves into a trunk of the vehicle, the trunk can be designed to automatically open upon a determination of the presence of any occupants in the trunk to thereby prevent children or pets from suffocating if inadvertently left in the trunk. In a similar manner, if the radio wave emitter and receiver emits radio waves into a passenger compartment of the vehicle, a window associated with the passenger compartment can be automatically opened upon a determination of the presence of any occupants in the passenger compartment to thereby prevent people or pets from suffocating if the temperature of the air in the passenger compartment rises to an dangerous level.

Referring now to FIGS. **20–27**, a section of the passenger compartment of an automobile is shown generally as **1000** in FIG. **20**. A driver of a vehicle **1101** sits on a seat **1102** behind a steering wheel **1103** which contains an airbag assembly **1104**. Five transmitter and/or receiver assemblies **1110, 1111, 1112, 1113** and **1114** are positioned at various places in the passenger compartment to determine the location of the head, chest and torso of the driver relative to the airbag. Usually, in any given implementation, only one or two of the transmitters and receivers would be used depending on their mounting locations as described below.

FIG. **20** illustrates several of the possible locations of such devices. For example, transmitter and receiver **1110** emits ultrasonic acoustical waves which bounce off the chest of the driver and return. Periodically a burst of ultrasonic waves at about 50 kilohertz is emitted by the transmitter/receiver and then the echo, or reflected signal, is detected by the same or different device An associated electronic circuit measures the time between the transmission and the reception of the ultrasonic waves and thereby determines the distance from the transmitter/receiver to the driver based on the velocity of sound. This information is then sent to the crash sensor and diagnostic circuitry which determines if the driver is close enough to the airbag that a deployment might, by itself, cause injury to the driver. In such a case the circuit disables the airbag system and thereby prevents its deployment. In an alternate case, the sensor algorithm assesses the probability that a crash requiring an airbag is in process and waits until that probability exceeds an amount that is dependent on the position of the occupant. Thus, for example, the sensor might decide to deploy the airbag based on a need probability assessment of 50%, if the decision must be made immediately for an occupant approaching the airbag, but might wait until the probability rises to 95% for a more distant occupant. Although a driver system has been illustrated, the passenger system would be identical.

In another implementation, the sensor algorithm may determine the rate that gas is generated to affect the rate that the airbag is inflated. In all of these cases the position of the occupant is used to affect the deployment of the airbag either as to whether or not it should be deployed at all, the time of deployment or as to the rate of inflation.

The ultrasonic transmitter/receiver **1110** is similar to that used on modern auto-focus cameras such as manufactured by the Polaroid Corporation. Other camera auto-focusing systems use different technologies, which are also applicable here, to achieve the same distance to object determination. One camera system manufactured by Fuji of Japan, for example, uses a stereoscopic system which could also be used to determine the position of a vehicle occupant providing there is sufficient light available. In the case of insufficient light, a source of infrared light can be added to illuminate the driver. In a related implementation, a source of infrared light is reflected off of the windshield and illuminates the vehicle occupant. An infrared receiver **1114** is located attached to the rear view mirror **1105**, as shown in FIG. **20**. Alternately, the infrared could be sent by the device **1114** and received by a receiver elsewhere. Since any of the devices shown in FIGS. **20** and **22** could be either transmitters or receivers or both, for simplicity, only the transmitted and not the reflected wave fronts are illustrated.

In the above-described system, a lens within receptor **1114** captures the reflected infrared light from the head or chest of the driver and displays it onto a charge coupled device (CCD), CMOS or equivalent array. One type of CCD is that used in television cameras to convert an image into an electrical signal. For the discussion of FIGS. **20–27** at least, a CCD will be used to include all devices which are capable of converting light frequencies, including infrared, into electrical signals. The CCD is scanned and the focal point of the lens is altered, under control of an appropriate circuit, until the sharpest image of the driver's head or chest results and the distance is then known from the focusing circuitry. The precision of this measurement is enhanced if two receptors are used which can either project images onto a single CCD or on separate CCD's. In the first case, one of the lenses could be moved to bring the two images into coincidence while in the other case the displacement of the images needed for coincidence would be determined mathematically. Naturally, other systems could be used to keep track of the different images such as the use of filters creating different infrared frequencies for the different receptors and again using the same CCD array. In addition to greater precision in determining the location of the occupant, the separation of the two receptors can also be used to minimize the effects of hands, arms or other extremities which might be very close to the airbag. In this case, where the receptors are mounted high on the dashboard on

either side of the steering wheel, an arm, for example, would show up as a thin object but much closer to the airbag than the larger body parts and, therefore, easily distinguished and eliminated, permitting the sensors to determine the distance to the occupant's chest. This is one example of the use of pattern recognition.

An optical infrared transmitter and receiver assembly is shown generally at **1112** in FIG. **20** and is mounted onto the instrument panel facing the windshield. Although not shown in this view, reference **1112** consists of three devices, one transmitter and two receivers, one on each side of the transmitter. In this case the windshield is used to reflect the illumination light, and also the light reflected back by the driver, in a manner similar to the "heads-up" display which is now being offered on several automobile models. The "heads-up" display, of course, is currently used only to display information to the driver and is not used to reflect light from the driver to a receiver. In this case, the distance to the driver is determined stereoscopically through the use of the two receivers. In its most elementary sense, this system can be used to measure the distance of the driver to the airbag module. In more sophisticated applications, the position of the driver, and particularly of the drivers head, can be monitored over time and any behavior, such as a drooping head, indicative of the driver falling asleep or of being incapacitated by drugs, alcohol or illness can be detected and appropriate action taken. Other forms of radiation including visual light, radar and microwaves as well as high frequency ultra sound could also be used by those skilled in the art.

Particular mention should be made of the use of radar since inexpensive antennas are now readily available. A scanning radar beam is used in this implementation and the reflected signal is received by a phase array antenna to generate an image of the occupant for input into the appropriate pattern detection circuitry. The word circuitry as used herein includes, in addition to normal electronic circuits, a microprocessor and appropriate software.

Electromagnetic or ultrasonic energy can be transmitted in three modes in determining the position of an occupant. In most of the cases disclosed above, it is assumed that the energy will be transmitted in a broad diverging beam which interacts with a substantial portion of the occupant. This method has the disadvantage that it will reflect first off the nearest object and, especially if that object is close to the transmitter, it may mask the true position of the occupant. This can be partially overcome through the use of the second mode which uses a narrow beam. In this case, several narrow beams are used. These beams are aimed in different directions toward the occupant from a position sufficiently away from the occupant that interference is unlikely. A single receptor could be used providing the beams are either cycled on at different times or are of different frequencies. Another approach is to use a single beam emanating from a location which has an unimpeded view of the occupant such as the windshield header. If two spaced apart CCD array receivers are used, the angle of the reflected beam can be determined and the location of the occupant can be calculated. The third mode is to use a single beam in a manner so that it scans back and forth or up and down, or in some other pattern, across the occupant. In this manner, an image of the occupant can be obtained using a single receptor and pattern recognition software can be used to locate the head or chest of the occupant. The beam approach is most applicable to electromagnetic energy but high frequency ultra sound can also be formed into a narrow beam.

The windshield header as used herein includes the space above the front windshield including the first few inches of the roof.

A similar effect to modifying the wave transmission mode can also be obtained by varying the characteristics of the receptors. Through appropriate lenses or reflectors, receptors can be made to be most sensitive to radiation emitted from a particular direction. In this manner a single broad beam transmitter can be used coupled with an array of focused receivers to obtain a rough image of the occupant.

Each of these methods of transmission or reception could be used, for example, at any of the preferred mounting locations shown in FIG. 20.

Another preferred location of a transmitter/receiver for use with airbags is shown at **1111** in FIG. **20**. In this case, the device is attached to the steering wheel and gives an accurate determination of the distance of the driver's chest from the airbag module. This implementation would generally be used with another device such as **1110** at another location.

Alternate mountings for the transmitter/receiver include various locations on the instrument panel on either side of the steering column such as **1113** in FIG. **20**. Also, although some of the devices herein illustrated assume that for the ultrasonic system the same device would be used for both transmitting and receiving waves, there are advantages in separating these functions. Since there is a time lag required for the system to stabilize after transmitting a pulse before it can receive a pulse, close measurements are enhanced, for example, by using separate transmitters and receivers. In addition, if the ultrasonic transmitter and receiver are separated, the transmitter can transmit continuously providing the transmitted signal is modulated in such a manner that the received signal can be compared with the transmitted signal to determine the time it took for the waves to reach and reflect off of the occupant. Many methods exist for this modulation including varying the frequency or amplitude of the waves or by pulse modulation or coding. In all cases, the logic circuit which controls the sensor and receiver must be able to determine when the signal which was most recently received was transmitted. In this manner, even though the time that it takes for the signal to travel from the transmitter to the receiver, via reflection off of the occupant, may be several milliseconds, information as to the position of the occupant is received continuously which permits an accurate, although delayed, determination of the occupant's velocity from successive position measurements. Conventional ultrasonic distance measuring devices must wait for the signal to travel to the occupant and return before a new signal is sent. This greatly limits the frequency at which position data can be obtained to the formula where the frequency is equal to the velocity of sound divided by two times the distance to the occupant. For example, if the velocity of sound is taken at about 1000 feet per second, occupant position data for an occupant located one foot from the transmitter can only be obtained every 2 milliseconds which corresponds to a frequency of 500 cycles per second.

This slow frequency that data can be collected seriously degrades the accuracy of the velocity calculation. The reflection of ultrasonic waves from the clothes of an occupant, for example, can cause noise or scatter in the position measurement and lead to significant inaccuracies in a given measurement. When many measurements are taken more rapidly, as in the technique described here, these inaccuracies can be averaged and a significant improvement in the accuracy of the velocity calculation results.

The determination of the velocity of the occupant need not be derived from successive distance measurements. A potentially more accurate method is to make use of the Doppler effect where the frequency of the reflected waves

differs from the transmitted waves by an amount which is proportional to the occupant's velocity. In a preferred embodiment, a single ultrasonic transmitter and a separate receiver are used to measure the position of the occupant, by the travel time of a known signal, and the velocity, by the frequency shift of that signal. Although the Doppler effect has been used to determine whether an occupant has fallen asleep, it has not heretofore been used in conjunction with a position measuring device to determine whether an occupant is likely to become out of position and thus in danger of being injured by a deploying airbag. This combination is particularly advantageous since both measurements can be accurately and efficiently determined using a single transmitter and receiver pair resulting in a low cost system.

Another preferred embodiment makes use of radio waves and a voltage-controlled oscillator (VCO). In this embodiment, the frequency of the oscillator is controlled through the use of a phase detector which adjusts the oscillator frequency so that exactly one half wave occupies the distance from the transmitter to the receiver via reflection off of the occupant. The adjusted frequency is thus inversely proportional to the distance from the transmitter to the occupant. Alternately, an FM phase discriminator can be used as known to those skilled in the art. These systems could be used in any of the locations illustrated in FIG. 20.

A passive infrared system could be used to determine the position of an occupant relative to an airbag. Passive infrared measures the infrared radiation emitted by the occupant and compares it to the background. As such, unless it is coupled with a pattern recognition system, it can best be used to determine that an occupant is moving toward the airbag since the amount of infrared radiation would then be increasing. Therefore, it could be used to estimate the velocity of the occupant but not his/her position relative to the airbag, since the absolute amount of such radiation will depend on the occupant's size, temperature and clothes as well as on his position. When passive infrared is used in conjunction with another distance measuring system, such as the ultrasonic system described above, the combination would be capable of determining both the position and velocity of the occupant relative to the airbag. Such a combination would be economical since only the simplest circuits would be required In one implementation, for example, a group of waves from an ultrasonic transmitter could be sent to an occupant and the reflected group received by a receiver. The distance to the occupant would be proportional to the time between the transmitted and received groups of waves and the velocity determined from the passive infrared system. This system could be used in any of the locations illustrated in FIG. 20 as well as others not illustrated.

Passive infrared could also be used effectively in conjunction with a pattern recognition system. In this case, the passive infrared radiation emitted from an occupant can be focused onto a CCD array and analyzed with appropriate pattern recognition circuitry, or software, to determine the position of the occupant. Such a system could be mounted at any of the preferred mounting locations shown in FIG. 20 as well as others not illustrated.

A transmitter/receiver 1215 shown mounted on the cover 1220 of the airbag module 1216 is shown in FIG. 21. The transmitter/receiver 1215 is attached to various electronic circuitry, not shown, by means of wire cable 1212. When an airbag 1218 deploys, the cover 1220 begins moving toward the driver. If the driver is in close proximity to this cover during the early stages of deployment, the driver can be seriously injured or even killed. It is important, therefore, to sense the proximity of the driver to the cover and if he or she gets too close, to disable deployment of the airbag 1218. An accurate method of obtaining this information would be to place the distance-measuring device onto the airbag cover 1220 as shown in FIG. 21. Appropriate electronic circuitry can be used to not only determine the actual distance of the driver from the cover but also his velocity as discussed above. In this manner, a determination can be made as to where the driver is likely to be at the time of deployment of the airbag 1218. This information can be used most importantly to prevent deployment but also to modify the rate of airbag deployment. In FIG. 20, for one implementation, ultrasonic waves are transmitted by a transmitter/receiver 1215 toward the chest 1222 of the driver. The reflected waves are then received by the same transmitter/receiver 1215.

One problem of the system using a sensor 1111 in FIG. 20 or sensor 1215 as shown in FIG. 21 is that a driver may have inadvertently placed his hand over the transmitter/receiver 1111 or 1215, thus defeating the operation of the device A second confirming transmitter/receiver 1110 is therefore placed at some other convenient position such as on the roof or headliner of the passenger compartment as shown in FIG. 22. This transmitter/receiver operates in a manner similar to 1111 and 1215.

A more complicated and sophisticated system is shown conceptually in FIG. 23 where transmitter/receiver assembly 1112 is illustrated. In this case, as described briefly above, an infrared transmitter and a pair of optical receivers are used to capture the reflection of the passenger. When this system is used to monitor the driver as shown in FIG. 23, with appropriate circuitry and a microprocessor, the behavior of the driver can be monitored. Using this system, not only can the position and velocity of the driver be determined and used in conjunction with an airbag system, but it is also possible to determine whether the driver is falling asleep or exhibiting other potentially dangerous behavior by comparing portions of his/her image over time. In this case the speed of the vehicle can be reduced or the vehicle even stopped if this action is considered appropriate. This implementation has the highest probability of an unimpeded view of the driver since he/she must have a clear view through the windshield in order to operate the motor vehicle.

Information is provided as to the location of the driver, or other vehicle occupant, relative to the airbag, to appropriate circuitry which will process this information and make a decision as to whether to prevent deployment of the airbag in a situation where it would otherwise be deployed, or otherwise affect the time of deployment. One method of determining the position of the driver as discussed above is to actually measure his or her position either using microwaves, optics or acoustics. An alternate approach, which is preferably used to confirm the measurements made by the systems described above, is to use information about the position of the seat and the seatbelt spool out to determine the likely location of the driver relative to the airbag. To accomplish this the length of belt material which has been pulled out of the seatbelt retractor can be measured using conventional shaft encoder technology using either magnetic or optical systems. An example of an optical encoder is illustrated generally as 1501 in FIG. 24. It consists of an encoder disk 1502 and a receptor 1503 which sends a signal to appropriate circuitry every time a line on the encoder disk passes by the receptor.

In a similar manner, the position of the seat can be determined through either a linear encoder or a potentiometer as illustrated in FIG. 25. In this case, a potentiometer

1601 is positioned along the seat track 1602 and a sliding brush assembly 1603 is used with appropriate circuitry to determine the fore and aft location of the, seat 1610. Naturally, for those seats which permit the seat back angle to be adjusted, a similar measuring system would be used to determine the angle of the seat back. In this manner the position of the seat relative to the airbag module can be determined. This information can be used in conjunction with the seatbelt spool out sensor to confirm the approximate position of the chest of the driver relative to the airbag.

For most cases, the seatbelt spool out sensor would be sufficient to give a good confirming indication of the position of the occupant's chest regardless of the position of the seat and seat back. This is because the seatbelt is usually attached to the vehicle at least at one end. In some cases, especially where the seat back angle can be adjusted, separate retractors would be used for the lap and shoulder portions of the seatbelt and the belt would not be permitted to slip through the "D-ring". The length of belt spooled out from the shoulder belt retractor then becomes a very good confirming measure of the position of the occupant's chest.

The occupant position sensor in any of its various forms can be integrated into the airbag system circuitry as shown schematically in FIG. 26 In this example, the occupant position sensors are used as an input to a smart electronic sensor and diagnostic system. The electronic sensor determines whether the airbag should be deployed based on the vehicle acceleration crash pulse, or crush zone mounted crash sensors, and the occupant position sensor determines whether the occupant is too close to the airbag and therefore that the deployment should not take place.

A particular implementation of an occupant position sensor having a range of from 0 to 2 meters (corresponding to an occupant position of from 0 to 1 meter since the signal must travel both to and from the occupant) using infrared is illustrated in the block diagram schematic of FIG. 27. The operation is as follows. A 48 MHz signal, f1, is generated by a crystal oscillator 1801 and fed into a frequency tripler 1802 which produces an output signal at 1.44 MHz. The 1.44 MHz signal is then fed into an infrared diode driver 1803 which drives the infrared diode 1804 causing it to emit infrared light modulated at 144 MHz and a reference phase angle of zero degrees. The infrared diode 1804 is directed at the vehicle occupant. A second signal f2 having a frequency of 48.05 MHz, which is slightly greater than f1, is also fed into a frequency tripler 1806 to create a frequency of 144.15 MHz. This signal is then fed into a mixer 1807 which combines it with the 144 MHz signal from frequency tripler 1802. The combined signal from the mixer 1807 is then fed to filter 1808 which removes all signals except for the difference, or beat frequency, between 3 times f1 and 3 times f2, of 150 kHz. The infrared signal which is reflected from the occupant is received by receiver 1809 and fed into pre-amplifier 1811. This signal has the same modulation frequency, 144 MHz, as the transmitted signal but now is out of phase with the transmitted signal by an angle x due to the path that the signal took from the transmitter to the occupant and back to the receiver. The output from pre-amplifier 1811 is fed to a second mixer 1812 along with the 144.15 MHz signal from the frequency tripler 1806. The output from mixer 1812 is then amplified by the automatic gain amplifier 1813 and fed into filter 1814. The filter 1814 eliminates all frequencies except for the 150 kHz difference, or beat, frequency in a similar manner as was done by filter 1808. The resulting 150 kHz frequency, however, now has a phase angle x relative to the signal from filter 1808. Both 150 kHz signals are now fed into a phase detector 1815 which determines the magnitude of the phase angle x. It can be shown mathematically that, with the above values, the distance from the transmitting diode to the occupant is x/345.6 where x is measured in degrees and the distance in meters.

The applications described herein have been illustrated using the driver of the vehicle. Naturally the same systems of determining the position of the occupant relative to the airbag apply to the passenger, sometimes requiring minor modifications. It is likely that the sensor required triggering time based on the position of the occupant will be different for the driver than for the passenger. Current systems are based primarily on the driver with the result that the probability of injury to the passenger is necessarily increased either by deploying the airbag too late or by failing to deploy the airbag when the position of the driver would not warrant it but the passenger's position would. With the use of occupant position sensors for both the passenger and driver, the airbag system can be individually optimized for each occupant and result in further significant injury reduction. In particular, either the driver or passenger system can be disabled if either the driver or passenger is out of position.

There is almost always a driver present in vehicles that are involved in accidents where an airbag is needed. Only about 30% of these vehicles, however, have a passenger. If the passenger is not present, there is usually no need to deploy the passenger side airbag. The occupant position sensor, when used for the passenger side with proper pattern recognition circuitry, can also ascertain whether or not the seat is occupied, and if not, can disable the deployment of the passenger side airbag and thereby save the cost of its replacement. A sophisticated pattern recognition system could even distinguish between an occupant and a bag of groceries, for example. Finally, there has been much written about the out of position child who is standing or otherwise positioned adjacent to the airbag, perhaps due to pre-crash braking. Naturally, the occupant position sensor described herein can prevent the deployment of the airbag in this situation.

FIG. 28 is a schematic drawing of one embodiment of an occupant restraint device control system in accordance with the invention. The first step is to obtain information about the contents of the seat at 900, when such contents are present on the seat. To this end, a presence sensor can be employed to activate the system only when the presence of an object, or living being, is detected. Next, at 902, a signal is generated based on the contents of the seat, with different signals being generated for different contents of the seat. Thus, while a signal for a dog will be different than the signal for a child set, the signals for different child seats will be not that different. Next, at 904, the signal is analyzed to determine whether a child seat is present, whether a child seat in a particular orientation is present and/or whether a child seat in a particular position is present. Deployment control 906 provides a deployment control signal or command based on the analysis of the signal generated based on the contents of the seat. This signal or command is directed to the occupant protection or restraint device 908 to provide for deployment for that particular contents of the seat. The system continually obtains information about the contents of the seat until such time as a deployment signal is received from, e.g., a crash sensor, to initiate deployment of the occupant restraint device.

FIG. 29 is a flow chart of the operation of one embodiment of an occupant restraint device control method in accordance with the invention. The first step is to determine whether contents are present on the seat at 910. If so,

information is obtained about the contents of the seat at **912**. At **914**, a signal is generated based on the contents of the seat, with different signals being generated for different contents of the seat. The signal is analyzed to determine whether a child seat is present at **916**, whether a child seat in a particular orientation is present at **918** and/or whether a child seat in a particular position is present at **920**. Deployment control **922** provides a deployment control signal or command based on the analysis of the signal generated based on the contents of the seat. This signal or command is directed to the occupant protection or restraint device **924** to provide for deployment for that particular contents of the seat. The system continually obtains information about the contents of the seat until such time as a deployment signal is received from, e.g., a crash sensor **926**, to initiate deployment of the occupant restraint device.

All of the above-described methods and apparatus may be used in conjunction with one another and in combination with the methods and apparatus for optimizing the driving conditions for the occupants of the vehicle described herein.

Although several preferred embodiments are illustrated and described above, there are possible combinations using other geometries, sensors, materials and different dimensions for the components that perform the same functions. This invention is not limited to the above embodiments and should be determined by the following claims.

We claim:

1. In a motor vehicle having an interior passenger compartment including a seat on which a child seat may be placed, a control system for controlling an occupant restraint device effective for protection of an occupant of the seat, comprising:

receiving means arranged in the vehicle for obtaining information about contents of the seat and generating a signal based on any contents of the seat, said receiving means being structured and arranged to generate a different signal for different contents of the seat when such contents are present on the seat;

analyzing means coupled to said receiving means for analyzing the signal in order to determine at least one of whether the contents of the seat include a child seat, whether the contents of the seat include a child seat in a particular orientation and whether the contents of the seat include a child seat in a particular position; and

deployment means coupled to said analyzing means for controlling deployment of the occupant restraint device based on the determination by said analyzing means.

2. The system of claim **1**, wherein said analyzing means are structured and arranged to determine whether the contents of the seat include a child seat in a rear-facing position.

3. The system of claim **1**, wherein said analyzing means are structured and arranged to determine the position of the child seat relative to the occupant restraint device.

4. The system of claim **1**, wherein said receiving means comprise wave transmitting means for transmitting waves toward the seat, wave receiving means arranged relative to said wave transmitting means for receiving waves reflected from the seat and a processor coupled to said wave receiver means for generating the different signal for the different contents of the seat based on the received waves reflected from the seat.

5. The system of claim **4**, wherein said wave receiving means comprise two wave receivers spaced apart from one another, said processor is structured and arranged to process the reflected waves from each of said receivers in order to create respective signals characteristic of the contents of the seat based on the reflected waves.

6. The system of claim **5**, wherein said analyzing means comprise categorization means coupled to said processor for categorizing said signals, said categorization means comprising pattern recognition means for recognizing and thus identifying the contents of the seat by processing said signals based on the reflected waves from the contents of the seat into a categorization of said signals characteristic of the contents of the seat.

7. The system of claim **6**, wherein said pattern recognition means comprise a trained neural network.

8. The system of claim **1**, wherein the occupant restraint device is a side airbag.

9. The system of claim **1**, wherein the child seat is provided with signal generating means for generating a reactive signal upon receipt of a transmitted signal, said receiving means being arranged to receive the reactive signal generated by said signal generating means.

10. The system of claim **9**, wherein said signal generating means comprise a resonator or reflector.

11. In a motor vehicle having an interior passenger compartment including a seat on which a child seat may be placed, a method for detecting the presence of a child seat on the seat, comprising the steps of:

obtaining information about contents of the seat;

generating a signal based on the information about the contents of the seat, a different signal being generated for different contents of the seat when such contents are present on the seat;

analyzing the signal in order to determine at least one of whether the contents of the seat include a child seat, whether the contents of the seat include a child seat in a particular orientation and whether the contents of the seat include a child seat in a particular position; and

controlling deployment of the occupant restraint device based on the analysis of the signal.

12. The method of claim **11**, wherein the step of analyzing the signal comprises the step of analyzing the signal to determine whether the contents of the seat include a child seat in a rear-facing position.

13. The method of claim **11**, further comprising the step of determining the position of the child seat, when present, relative to the occupant restraint device, deployment of the occupant restraint device being controlled based on the determination of whether the contents of the seat include a child seat and the position of the child seat.

14. The method of claim **11**, wherein the step of obtaining information about the contents of the seat comprises the steps of transmitting waves toward the seat and receiving waves reflected from the seat, the step of generating a signal based on the information about the contents of the seat comprising the step of processing the received, reflected waves in order to generate a different signal for different received, reflected waves.

15. The method of claim **14**, wherein the step of processing the reflected waves comprises the step of categorizing said signal to thereby obtain an identification of the contents of the seat.

16. The method of claim **11**, wherein the occupant restraint device is a side airbag.

17. The method of claim **11**, wherein the step of obtaining information about the seat comprises the steps of providing the child seat with signal generating means for generating a reactive signal upon receipt of a transmitted signal and processing the reactive signal generated by the signal generating means.

18. The method of claim **17**, wherein the signal generating means comprise a resonator or reflector.

19. A vehicle including a system for obtaining information about an object in the vehicle, comprising:

at least one resonator arranged in association with the object, said at least one resonator being arranged to emit an energy signal upon receipt of a signal at an excitation frequency;

transmitter means for transmitting signals at least at the excitation frequency of each of said at least one resonator,

energy signal detector means for detecting the energy signal emitted by said at least one resonator upon receipt of the signal at the excitation frequency;

a processor coupled to said detector means for obtaining information about the object upon analysis of the energy signal detected by said detector means;

an occupant restraint system for protecting the object, said occupant restraint system including a side airbag arranged to deploy along a right or left side of the vehicle; and

deployment means coupled to said processor for controlling deployment of said occupant restraint system based on the information obtained about the object.

20. The vehicle of claim 19, wherein the information obtained about the object is a distance between each of said at least one resonator and said detector means.

21. The vehicle of claim 19, wherein the object is a seat whereby the information obtained about the seat is an indication of the position of the seat.

22. The vehicle of claim 19, wherein said at least one resonator comprises a plurality of resonators, each of said resonators being arranged to emit an energy signal upon receipt of a signal at a different excitation frequency.

23. The vehicle of claim 19, wherein the object is a seatbelt whereby the information obtained about the seatbelt is at least one of an indication of whether the seatbelt is in use and an indication of the position of the seatbelt.

24. The vehicle of claim 19, wherein the object is a child seat whereby the information obtained about the child seat is at least one of an indication of the orientation of the child seat and an indication of the position of the child seat.

25. The vehicle of claim 19, wherein the object is a window of the vehicle whereby the information obtained about the window is an indication of whether the window is open or closed.

26. The vehicle of claim 19, wherein the object is a door, said at least one resonator being arranged in a surface facing the door such that closure of the door prevents emission of the energy signal from said at least one resonator, whereby the information obtained about the door is an indication of whether the door is open or closed.

27. The vehicle of claim 19, wherein said at least one resonator comprises a tuned resonator including an acoustic cavity or a vibrating mechanical element.

28. The vehicle of claim 19, wherein said processor is arranged to determine the position of the object upon analysis of the energy signal detected by said detector means.

29. The vehicle of claim 19, wherein said at least one resonator comprises a plurality of resonators, all arranged in association with the same object.

30. The vehicle of claim 19, wherein said at least one resonator comprises a dual frequency resonator.

31. The vehicle of claim 19, wherein said deployment means are arranged to adjust at least one of the rate of inflation of said side airbag, the time of inflation of said side airbag, the rate of deflation of said side airbag and the time of deflation of said side airbag.

32. A vehicle including a system for obtaining information about an object in the vehicle, comprising:

at least one reflector arranged in association with the object, said at least one reflector being arranged to reflect an energy signal;

transmitter means for transmitting energy signals in a direction of each of said at least one reflector;

energy signal detector means for detecting energy signals reflected by said at least one reflector;

a processor coupled to said detector means for obtaining information about the object upon analysis of the energy signal detected by said detector means;

an occupant restraint system for protecting the object, said occupant restraint system including a side airbag arranged to deploy along a right or left side of the vehicle; and

deployment means coupled to said processor for controlling deployment of said occupant restraint system based on the information obtained about the object.

33. The vehicle of claim 32, wherein said at least one reflector comprises a parabolic-shaped reflector.

34. The vehicle of claim 32, wherein the information obtained about the object is a distance between each of said at least one reflector and said detector means.

35. The vehicle of claim 32, wherein the object is a seat whereby the information obtained about the seat is an indication of the position of the seat.

36. The vehicle of claim 32, wherein the object is a seatbelt whereby the information obtained about the seatbelt is at least one of an indication of whether the seatbelt is in use and an indication of the position of the seatbelt.

37. The vehicle of claim 32, wherein the object is a child seat whereby the information obtained about the child seat is at least one of an indication of the orientation of the child seat and an indication of the position of the child seat.

38. The vehicle of claim 32, wherein the object is a window of the vehicle whereby the information obtained about the window is an indication of whether the window is open or closed.

39. The vehicle of claim 32, wherein the object is a door, said at least one reflector being arranged in a surface facing the door such that closure of the door prevents reflection of an energy signal by said at least one reflector, whereby the information obtained about the door is an indication of whether the door is open or closed.

40. The vehicle of claim 32, wherein said transmitter means comprise an infrared laser system and said at least one reflector comprises an optical mirror.

41. The vehicle of claim 32, wherein said processor is arranged to determine the position of the object upon analysis of the energy signal detected by said detector means.

42. The vehicle of claim 32, wherein said at least one reflector comprises a plurality of reflectors, all arranged in association with the same object.

43. The vehicle of claim 32, wherein said deployment means are arranged to adjust at least one of the rate of inflation of said side airbag, the time of inflation of said side airbag, the rate of deflation of said side airbag and the time of deflation of said side airbag.

44. A vehicle including a system for obtaining information about an object in the vehicle, comprising:

at least one resonator arranged in association with the object, said at least one resonator being arranged to emit an energy signal upon receipt of a signal at an excitation frequency;

transmitter means for transmitting signals at least at the excitation frequency of each of said at least one resonator;

energy signal detector means for detecting the energy signal emitted by said at least one resonator upon receipt of the signal at the excitation frequency;

a processor coupled to said detector means for obtaining information about the object upon analysis of the energy signal detected by said detector means;

an occupant restraint system for protecting the object and including at least one airbag; and

deployment means coupled to said processor for adjusting deployment of said occupant restraint system based on the information obtained about the object, said deployment means being arranged to adjust at least one of the rate of inflation of said at least one airbag, the time of inflation of said at least one airbag, the rate of deflation of said at least one airbag and the time of deflation of said at least one airbag.

45. The vehicle of claim **44**, wherein said processor is arranged to determine the position of the object upon analysis of the energy signal detected by said detector means.

46. A vehicle including a system for obtaining information about an object in the vehicle, comprising:

at least one reflector arranged in association with the object, said at least one reflector being arranged to reflect an energy signal;

transmitter means for transmitting energy signals in a direction of each of said at least one reflector;

energy signal detector means for detecting energy signals reflected by said at least one reflector;

a processor coupled to said detector means for obtaining information about the object upon analysis of the energy signal detected by said detector means;

an occupant restraint system for protecting the object and including at least one airbag; and

deployment means coupled to said processor for adjusting deployment of said occupant restraint system based on the information obtained about the object, said deployment means being arranged to adjust at least one of the rate of inflation of said at least one airbag, the time of inflation of said at least one airbag, the rate of deflation of said at least one airbag and the time of deflation of said at least one airbag.

47. The vehicle of claim **46**, wherein said processor is arranged to determine the position of the object upon analysis of the energy signal detected by said detector means.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,942,248 B2

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INVENTOR(S) : David S. Breed et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

<u>Column 1,</u>
Line 12, change "6,513,853" to -- 6,513,833 --.

<u>Column 22,</u>
Line 24, change "cars" to -- ears --.

<u>Column 26,</u>
Line 20, change "110A" to -- 101A --.

Signed and Sealed this

First Day of November, 2005

Jon W. Dudas

JON W. DUDAS

Director of the United States Patent and Trademark Office